BIG BORE TRANSCEIVER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit under 35 USC §119 of the filing date of international application PCT/US02/27861 filed September 3, 2002, the disclosure of which is incorporated herein by this reference.

TECHNICAL FIELD

The present invention relates generally to subterranean well apparatus and, in an embodiment described herein, more particularly provides an improved acoustic transmission system for use in subterranean well applications.

BACKGROUND

In subterranean well completions, of both surface and subsea types, a metal tubing structure such as production tubing is typically supported from an appropriate metal hanger structure and extends downwardly therefrom through the wellbore portion of the

completion which is normally lined with a metal casing structure. It is often desirable to monitor the state of various downhole well parameters such as, for example but not by way of limitation, the temperatures and pressures within the tubing and external to the tubing in an annular space defined between the tubing and the casing. Many times the desired sensing locations for these well parameters are thousands of feet downhole. Thus, signals indicative of the sensed well parameters must correspondingly be tubing wall-transmitted upwardly through great distances via the wellbore (and a lengthy undersea riser in a subsea application) to a predetermined signal receiving location.

Various techniques have previously been proposed for generating and transmitting these well parameter signals. One such technique has been to transmit acoustic signals upwardly through the downhole metal wall portion of the tubing structure and then to the signal receiving location, via the wall portion of the remainder of the tubing structure, for conversion to, for example, digital or analog electrical signals.

A substantial impediment to successfully utilizing this acoustic-based signal transmission technique has been the necessary presence of a metal hanger structure from which the metal tubing structure is supported. In a subsea application, this metal hanger structure is typically a fluted hanger assembly, and in a surface application it is typically a slip structure. In either case, due to the metal-to-metal contact between the hanger structure and the tubing the hanger structure substantially dissipates an acoustic signal reaching it via a downhole portion of the tubing wall.

Accordingly, the acoustic signal reaching the tubing wall section uphole of the hanger structure is substantially weakened. In the case of a subsea well application, this weakened signal may then have to travel thousands of feet upwardly through the tubing wall above the hanger structure to reach the signal receiving location. Thus, the through-tubing acoustic transmission of downhole well parameter signals to a signal receiving location uphole of the well completion hanger structure has proven difficult, and in many applications unfeasible, to implement. A need thus exists for an improved acoustic-based signal transmission system in a well completion. A need additionally exists to transmit acoustical signals downwardly past the hanger structure, to a downhole location, to actuate devices and reconfigure acoustic transmission devices for better communications.

SUMMARY

In carrying out the principles of the present invention, in accordance with an embodiment thereof, a subterranean well completion is provided which comprises a wellbore extending into the earth, a tubular structure extending into the wellbore, and an acoustic energy dissipating well structure, representatively a hanger structure, which engages the tubular structure, with an upper portion of the tubular structure extending upwardly from the hanger structure, and a lower portion of the tubing structure extending downwardly from the hanger structure and through the wellbore.

The well completion, which may be a subsea completion or a surface-based completion, further comprises a specially designed

signal transmission system operable to transmit an acoustic signal, representatively a downhole well parameter signal, upwardly through the lower tubing structure section toward the hanger structure from a downhole location, convert the acoustic signal to a non-acoustic signal at a location on the lower tubing structure section below the hanger structure, and transmit the converted, non-acoustic signal from an output section of the signal transmission system through a signal path structure coupled between the output section and a signal receiving location disposed above the hanger structure. Since the initially acoustic downhole well parameter signal is converted to a non-acoustic signal below the hanger structure, the substantial acoustic dissipation characteristic of the hanger structure does not appreciably weaken the signal eventually reaching the signal receiving location.

In an illustrated embodiment thereof, a signal transmission apparatus portion of the overall signal transmission system includes a lower transceiver structure connected in the lower tubing structure section below the hanger and operative to acoustically transmit the predetermined well parameter signal upwardly through the lower tubing structure section toward the hanger structure, and an upper transceiver structure, having a transceiver portion and a signal converting portion, disposed in the lower tubing structure portion between the hanger structure and the lower transceiver structure. The upper transceiver structure is representatively of a tubular configuration and has an axial bore with a diameter substantially equal to that of the lower tubing structure section, and receives the acoustic signal, converts it to a non-acoustic form, and outputs the converted signal to the signal path structure. The

converted signal may, for example but not by way of limitation, be a digital or analog electric signal, a photoelectric signal, or an electromagnetic signal.

In one version of the well completion, the signal path includes a signal cable structure extending through the hanger structure and routed upwardly along the upper tubing structure section and through and/or around various well components mounted in the upper tubing structure section. In another version of the well completion, the signal path structure extends externally around the hanger structure and representatively includes a portion of the earth adjacent the upper transceiver structure. In this version, incorporated in a subsea embodiment of the well completion, the upper transceiver structure outputs electromagnetic wave signals which are propagated through the earth and received by a transmitter disposed on the sea bed and having an output cable for transmitting the received signal upwardly through the water to the signal receiving location.

Preferably, the signal transmission system is also capable of downwardly transmitting control signals, via the signal path structure and the tubing structure, to the lower transceiver structure to modify various aspects of the signal transmission system, including but not limited to changing the predetermined sensed downhole well parameter, changing the parameter value range associated with the downhole well parameter, changing the type of data transmitted by the lower transceiver structure, and changing the type of data transmitted by the lower transceiver structure. In addition, the downward transmission of control signals

could be utilized to actuate downhole actuators such as valves or pumps to modify well test parameters.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view through a portion of a representative subsea subterranean well completion having incorporated therein a specially designed acoustic transmission system embodying principles of the present invention;

FIG. 2 is an enlargement of a portion of the FIG. 1 well completion;

FIG. 3 is a schematic cross-sectional view of a portion of a first alternate embodiment of the FIG. 1 well completion;

FIG. 4 is a schematic cross-sectional view of a portion of a second alternate embodiment of the FIG. 1 well completion;

FIG. 5 is a schematic cross-sectional view of a portion of a third alternate embodiment of the FIG. 1 well completion; and

FIG. 6 is a schematic partly cross-sectional, partly elevational view of a non-subsea version of the FIG. 1 subterranean well completion.

DETAILED DESCRIPTION

Representatively and schematically illustrated in FIGS. 1 and 2 are longitudinal portions of a subsea subterranean well completion 10 which embodies principles of the present invention. In the following description of the well completion 10 and other apparatus and methods described herein, directional terms, such as "above", "below", "upper", "lower", etc., are used only for convenience in referring to the accompanying drawings. Additionally, it is to be

understood that the various embodiments of the present invention described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present invention.

With reference to FIGS. 1 and 2, the well completion 10 includes a representatively vertical wellbore 12 extending downwardly from the sea bed 14 into the underlying earth 16, the wellbore 12 being lined with a tubular metal casing 18 extending downwardly form the sea bed 14. A smaller diameter metal tubing structure 20 extends centrally through the casing 18 and forms therewith an annulus 22 laterally circumscribing the tubing 20. As illustrated, the tubing 20 has an upper section that extends upwardly from the sea bed 14 sequentially through an undersea wellhead/blowout preventer structure 24 and a tubular riser 26 extending upwardly from the structure 24 through the water 28 to a rig floor 30.

Operatively mounted in the section of the tubing 20 above the sea bed 14, and of conventional construction, are (from bottom to top as viewed in FIGS. 1 and 2) a longitudinally ported tubular slick joint 32, a subsea test tree 34, and an electrohydraulic module 36, the structures 32 and 34 being disposed within the wellhead/BOP (blow out preventer) structure 24, and the structure 36 being in the riser 26 above the wellhead/BOP 24. Disposed within the wellhead/BOP 24 are conventional ram and shear ram sets 38,40 that respectively oppose the slick joint 32 and a section of the tubing 20 between the test tree 34 and the electrohydraulic module 36.

Operatively disposed at sea bed level beneath the slick joint 32 is a conventional metal fluted tubing hanger structure 42 that

includes a metal hanger member 44 anchored to the tubing 20, and a metal wear bushing structure 46 complementarily engaged by the metal hanger member 44. In a manner subsequently described herein, downhole well parameters (such as, but not limited to, pressures and temperatures within the tubing 20 and the annulus 22) are sensed and acoustic signals indicative of the sensed downhole well parameters are responsively transmitted upwardly through the metal wall of the downhole section of the tubing 20.

Conventional attempts to utilize acoustic well parameter indicating signals transmitted through the tubing, and ultimately received at an uphole signal converting station, have typically been frustrated by the presence of the hanger structure 42 which, due to its metal-to-metal contact with the tubing 20, substantially dissipates an acoustic signal traveling through the tubing upwardly through the hanger structure. Simply stated, the attenuated acoustic signal exiting the hanger structure via the tubing section above the hanger structure tends to be too weak to be useful.

To overcome this problem, the present invention incorporates in the well completion a specially designed acoustic-based signal transmission system which, as will now be described, generates acoustic well parameter signals in the wellbore below the hanger structure 42, transmits the acoustic signals upwardly through the tubing 20 to a conversion point therein downhole of the hanger structure 42 at which the acoustic signals are converted to a non-acoustic form, and then transmits the converted signals to a signal receiving location uphole from the hanger structure 42. In this manner the undesirable acoustic attenuation properties of the hanger structure 42 do not adversely affect the quality and strength

of the well parameter signals ultimately reaching the signal receiving location.

With continuing reference to FIGS. 1 and 2, the acoustic transmission system includes a first acoustic transceiver structure 48 (see FIG. 1) which is of a suitable conventional construction and is representatively secured to the lower end of the tubing 20 within the cased wellbore 12. Transceiver or well tool structure 48 functions to monitor at least one downhole well parameter and responsively transmit an acoustic signal, which is indicative of the value of the sensed parameter, upwardly through the metal wall of the tubing 20 toward the hanger structure 42.

The acoustic transmission system also includes a second acoustic transceiver structure 50 which is secured in-line in the tubing 20 above the transceiver 48 and somewhat below the hanger structure 40. In a simplified uplink system, the second transceiver structure could consist of a suitable acoustic wave measurement sensor, and a signal amplifier, and a suitable packaging structure. The acoustic measurement sensor would convert the acoustic signals into non-acoustic signals, preferably electrical signals. The electrical signals could be amplified and transported to the surface by the signal amplifier. Equipment at the surface would decode the signals to obtain the downhole well parameters.

The transceiver structure 50 schematically depicted in FIGS. 1 and 2 representatively includes an acoustic transceiver 52 and an associated signal converter section 54. Transceiver 52 representatively has a resonant stack construction similar to a transceiver construction illustrated in U.S. Patent 6,137,747 which is hereby incorporated herein by reference. A central circular bore 56,

having a diameter substantially identical to that of the interior of the tubing 20, axially extends through the acoustic transceiver structure 50 between its upper and lower ends. Representatively, a suitable conventional acoustic signal repeater 58 (see FIG. 1) is mounted in the tubing 20 between the first and second acoustic transceiver structures 48,50.

During operation of the acoustic transmission system, at least one sensed well parameter signal is transmitted, in acoustic form, upwardly from the first acoustic transceiver structure 48, through the metal wall of the tubing 20, to the repeater 58 which, in turn, sends a corresponding acoustic signal through the tubing wall to the transceiver portion 52 of the upper acoustic transceiver structure 50.

According to a key aspect of the present invention, the signal converter section 54 of the upper transceiver structure 50, which is disposed below the hanger structure 42, receives these acoustic signals and converts them to non-acoustic signals such as, for example, digital electrical signals, analog electrical signals or photoelectric signals. These converted, non-acoustic signals are then transmitted to a remote signal receiving location (not illustrated) disposed, for example, on the rig (offshore) or wellsite (onshore). As illustrated in FIGS. 1 and 2, these converted, non-acoustic signals are routed upwardly from the signal converter portion 54 of the upper transceiver structure 50 to the signal receiving location via a signal transmission cable structure 60. Because acoustic signals are not passed upwardly through the hanger structure 42 (which, as previously discussed herein, is a structure which would otherwise greatly dissipate tubing-carried acoustic signals passing upwardly therethrough), the hanger structure 42 does not appreciably weaken

well parameter and audio signals ultimately reaching the signal receiving location.

From its connection to the signal converter portion 54 the cable 60 sequentially passes upwardly through the hanger member 44, upwardly through a vertical sidewall port in the ported tubular slick joint 32, upwardly around the exterior of the subsea test tree 34, and upwardly along the exterior of an adjacent section of the tubing 20 to a cable connection portion 62 of the electrohydraulic module 36. From the electrohydraulic module 36 the converted signals are routed to the signal receiving location via electrohydraulic cabling 64 wrapped around an upper end portion of the tubing 20 and operatively connected to an electrohydraulic reel 66 (see FIG. 1) disposed on the rig. From the reel 66 the converted signals are routed to the signal receiving location via a schematically depicted electrical wire connection 68 coupled to the reel 66. Thus, as to the acoustic downhole well parameter and audio signals there is an acoustic signal transmission path disposed beneath the hanger structure 42, and a non-acoustic signal path which extends upwardly past the hanger structure 42 and forms at least a portion of the remaining signal path routed to the signal receiver location.

While this non-acoustic signal transmission path has been representatively depicted herein as being a cabled path extending clear to the surface and carrying electric or photoelectric converted signals, other types of non-acoustic signal transmission paths could alternatively be provided above the hanger structure or other source of substantial attenuation of through-tubing acoustic signal strength. For example, as subsequently discussed herein, this non-acoustic signal transmission path extending above the hanger

structure could include an electromagnetic path emanating from the signal converter 54. Alternatively, once the converted non-acoustic signal path upwardly passes the hanger structure 42, the non-acoustic signal could be re-converted to acoustic form and transmitted through an upper portion of the tubing 20 (as indicated by the dashed arrow "A" in FIG. 2) to the surface.

Since the signal transmission components 48,50 are both transceiver structures they are, of course, capable of both transmitting and receiving signals. In the well completion 10 representatively depicted in FIGS. 1 and 2, various control signals may also be transmitted (from the signal receiving location) through the overall illustrated signal path downhole to the lower transceiver structure 48. These control signals are sequentially transmitted in non-acoustic form through the cabling 62,60 through the hanger member 44, and then converted to acoustic form by the signal converter 54 and acoustically transmitted downwardly through the tubing wall, via the repeater 58, to the lower transceiver structure 48. The control signals sent in this manner to the transceiver structure 48 may be utilized in a variety of manners including, for example but not by way of limitation, to change in the lower transceiver structure the sensed downhole well parameter(s), the ranges of parameter value(s) sensed, the transmission frequency, or the type of data transmitted.

The representative signal transmission system just described may be incorporated in a variety of well completions having configurations different than that shown in FIGS. 1 and 2. For example, the subsea well completion embodiment 10a shown in FIG. 3 does not have an electrohydraulic module such as the

electrohydraulic module 34 shown in FIG. 2. Accordingly, above the subsea test tree 34, the cable 60 is wrapped around the tubing 20 and extended to the surface for routing to the signal receiving location.

The subsea well completion embodiment 10b shown in FIG. 4 is similar to that shown in FIG. 3, with the exception that the subsea test tree 34 has a built in electrical feed-through portion 70 to which portions of the cable 60 above and below the feed-through portion 70 are operatively connected.

As previously mentioned herein, the converted signal path which, in effect, "bypasses" the undesirable acoustic attenuation of the hanger structure 42 is not limited to a wholly or partly electrical or photoelectric nature. For example, in the subsea well completion embodiment 10c shown in FIG. 5, the signal converter portion 54 of the upper transceiver structure 50 is operative to convert its received acoustic signals to electromagnetic waves 72 which are transmitted through the earth 16 to a suitable transceiver structure 74 located on the sea bed 14 and coupled to a cable structure 76 extending upwardly through the water 28 to the signal receiving location. Upon receiving the electromagnetic signals 72, the transceiver structure 74 converts them to suitable electrical form for upward transmission through the cable structure 76. Of course, signals may also be transmitted downwardly through this overall transmission path to the upper transceiver structure 50 for transmission therefrom to the lower transceiver structure 48.

The signal transmission system of the present invention may also be incorporated in a land-based well completion such as the well completion embodiment 10d schematically depicted in FIG. 6. In this

well completion, in which a rig floor 78 is disposed above the earth's surface 80, and the tubing 20 extends upwardly from the ported tubular slick joint 32 to schematically depicted surface equipment 82, the acoustic-attenuating hanger structure is defined by metal slips 84 which engage the slick joint 32. In well completion 10d, the portion of the cable 60 upwardly exiting the slick joint 32 is appropriately routed to the signal receiving location.

The foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the present invention being limited solely by the appended claims.